METHANE FROM GIN AND DAIRY WASTES

Paul A. Funk, Carlos B. Armijo
USDA-ARS-SW Cotton Ginning Research Lab, Mesilla Park, NM
Adrian T. Hanson, Zohrab A. Samani, Geoffrey B. Smith and Skye J.T. Riordan
New Mexico State University, Las Cruces, NM

Abstract

Economically productive alternatives to gin trash disposal would benefit the ginning industry. Combining gin and dairy wastes in a two-phase anaerobic system produces methane gas and a class A soil amendment. This optimization experiment indicated process completion in three weeks is possible with temperatures above 32 C (90 F), mixture ratios above 5:1 (gin to dairy waste, dry basis) and twice daily wetting of the solid phase. Ten percent of the mass was converted to soluble chemical oxygen demand, which potentially can be converted to methane in the second phase, at from 70 to 80% concentration. Fecal coliform and salmonella bacteria counts fell even though temperatures were below the pasteurization level.

Introduction

Cotton Gin Byproducts

Cotton ginning involves removal of both seeds and foreign matter from cotton lint. While the market for cotton seed is well established (if not very lucrative), other byproducts are not always utilized to their full potential. With spindle-picked cotton, 680 kg (1500 pounds) of seed cotton are ginned to make a 227 kg (500 pound) bale of lint. The balance is approximately 363 kg (800 pounds) seed and 91 kg (200 pounds) trash. With stripper-harvested cotton, as much as 907 kg (2,000 pounds) of seed cotton per finished bale come to the gin, 318 kg (700 pounds) being trash. The seed is crushed for oil or fed to cattle. The trash, mostly leaf material, stems and hulls, is in some areas sold as bedding for livestock or as mulch for field application. In other parts of the country it is a financial liability. Roughly half the gins in the United States spend money disposing of this resource.

Meanwhile, back at the ranch

New Mexico has the largest average dairy herd size (1,700 head) in the nation. New Mexico is currently ranked 7th in the nation for milk production. The dairy (and feeding) industry is facing increasing pressure to dispose of concentrated quantities of fecal material in ways that do not expose the public to pathogens and the ground water to nitrates. This paper describes an attempt to create a market for the ginning industry's other byproduct by combining it with a byproduct from the dairy/feedlot industry, producing both energy and a class A soil amendment (less than 1,000 most probable number *e. coli* or salmonella colonies per gram). Additionally, the two-phase process reduces salt concentration.

Biphasic biofermentation

A two-phase process proposed by Pohland and Ghosh (1971) was selected where the bacteria that break down cellulose and produce volatile fatty acids (VFA) are active in one location, and the anaerobic bacteria that form methane are nurtured in a separate reactor vessel (Figure 1). This results in a higher quality gas (the carbon dioxide produced by the VFA formers does not dilute the methane) and a lower capital and operating cost (smaller anaerobic vessel, less water and more rapid cycling). A complete prototype system operated at New Mexico State University provided full-scale methane production data. A smaller-scale study was conducted at the USDA-ARS Southwestern Cotton Ginning Research Laboratory to discover optimum operating parameters for the solid phase portion. Chemical Oxygen Demand (COD) data from both studies was used to predict potential methane production for the optimization study. Both studies traced fecal coliform bacteria populations as an indicator of pathogens.

Materials and Methods

Pilot Plant Study

Cotton gin trash including lint (the mote bale press was not being used at the time) was combined with fresh bovine manure screenings flushed from a dairy milk parlor. The ratio of gin trash to manure was approximately 1:1 (wet manure). This material was layered in an 8 cubic meter (300 cu. ft.) steel dumpster modified to be gas-tight. Pumps circulated water from the sump area at the bottom of the dumpster twice daily through nozzles above the pile to keep it saturated. Once a day other pumps fed the leachate to two heated anaerobic columns containing established colonies of methanogenic bacteria growing on porous plastic spheres. These columns, or upflow anaerobic filters, were each 0.3 m dia. X 3.6 m high (12 in x 12 ft) and held approximately 190 L (50 gal). Product gas was quantified and sampled for methane fraction. COD, pH and pathogens were sampled daily.

Solid Phase Optimization Study

Cotton gin trash including lint (the mote bale press was not being used at the time) was combined with dry bovine manure scraped from a dairy feed lot and aged for from 1 to three months. The ratio of gin trash to manure (varied according to the experimental design in Table 1) ranged from 1:1 to 10:1 dry mass basis. This mixture was wetted (using 0.125% Induce ™, a surfactant) and layered in 38 liter (10 gal.) plastic tanks. Each tank drained into a 19 liter (5 gal.) plastic bucket equipped with a recirculation pump. The pumps were activated by timers on a schedule (according to the experimental design in Table 1) from one minute every 2 hours to one minute every 24 hours, returning leachate to the top of the tank. Each tank was in a 135 liter (35 gal.) galvanized steel garbage can equipped with insulation and an electric heating element. The temperature in the tanks was controlled (according to the experimental design in Table 1) and ranged from 20 to 45 C (68 to 113 F). A central composite experimental design was selected to find the optimum combination of mixture, temperature and wetting frequency. The two response variables measured were time to complete the process (minimum time being desirable) and cumulative COD (COD production predicting methane production, maximum being desired).

Twenty lots (six replicates at the center to determine pure error, eight corner points and six axial points) were run in sets of four, from May through December of 2002. Each day the leachate was replaced with two liters of fresh water, simulating consumption of the volatile fatty acids by the missing methanogenic bacteria. Fresh leachate was probed for pH and NaCl, and 125 ml samples were collected and refrigerated for later COD analysis.

Pathogen Liability

A four lot run comparing pathogen liability was interspersed in the middle of the twenty lots called for by the experimental design. In this secondary analysis all four tanks had 5 kg fresh bovine manure screenings flushed from a dairy milk parlor (83% moisture) and two tanks had 5 kg of cotton gin trash mixed with and in addition to the manure screenings. The operational center point was chosen to provide some degree of replication; all four tanks were run at 32.5 C (90.5 F), with wetting every 8 hours. Membrane filtration counts were performed following standard methods (Water Environment Federation, 1998).

Results and Discussion

Pilot Plant Study

Two thirds of the volatile solids in the waste material were converted to soluble COD. Methane production in the anaerobic columns was proportional to COD content in the feed water. Yield at standard conditions was 0.34 m^3 per kg COD. Maximum COD values in this trial were 35,000 mg/L. Methane averaged 71% in product gas (Yu et al., 2002).

Solid Phase Optimization Study

The most significant main effect was temperature (1.6 % osl), followed by mixture ratio (3% osl). Increasing temperature from 25 to 44 C (76 to 111 F) decreased completion time as did increasing the dry manure portion (from 1:10 to 1:1) (Figure 2). Frequency of wetting had only a minor influence on time to complete acidogenisis. The mean time to completion was 21 days. COD production typically fell below 5,000 mg/L four days after the pH began to rise. Cumulative COD for each 10 kg (22 pound) batch of dry feedstock was typically 1 kg to 1.2 kg, corresponding to a potential methane production of from 0.4 to 0.5 m^3 in each tank. Cumulative COD production appeared to decrease with increasing temperature, but there is no statistical significance to support this observation; eight of twenty lots had to be excluded due to missing data. A leading indicator of completion was the sudden rise in pH level caused by VFA bacteria exhausting their food supply (Figures 3, 4).

Based on these results, insulation and/or supplemental heating appears to be of greater value than frequent pumping providing the pile is wetted daily. Maintaining the dairy waste proportion above 20% dry basis contributes to a more rapid completion as well. Non-ionic surfactants aid in wetting the gin trash layers. Salt was washed out of the solid-phase during the process (leachate sodium went from over 10,000 to under 2,000 ppm). Composting results in a soil amendment that is 36.39 % organic material. Elements (ppm) were: Mg; 99.63, Ca; 328.66, Na; 90.81, N; 2.9, P; 449.0, K; 654. Operating systems are envisioned that would have at least two active solid phase piles with at least one additional solid phase cell area being available for loading wastes and unloading product. Covers are not required for anaerobic conditions in the solid phase portion, but they help contain insect pests and oders.

Pathogen Liability

We have observed reproducible disinfection of the coliform loads resident in the manure and a statistically significant difference in the decontamination capacity of digesters charged with manure alone vs. co-charged with gin trash and manure. Despite the fact that the solid phase never exceeded 37 C (99 F), the fecal coliform indicator organism (*e-coli*) normally associated with pathogenic bacteria decreased from an initial count of log 8 to 8.5 down to log 3.5 to 4 after 21 days in the presence of gin trash (coliform units per hundred ml). Without gin trash present final counts were log 5.5 to 6 CFU/100 ml. (See table 2) At this point we are unable to explain the mechanism of disinfection.

Disclaimer

"Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U. S. Department of Agriculture."

References

Pohland, F.G. and S. Ghosh. 1971. Developments in anaerobic treatment process. *Biotechnol and Bioeng* 2:85-106.
Water Environment Federation (WEF). 1998. Standard Methods for the Examination of Water and Wastewater - 20th Ed.
Yu, H. W., Z. Samani, A. Hanson and G. Smith. 2002. Energy recovery from grass using two-phase anaerobic digestion. *Waste Management* 22:1-5.

Table 1. Experiment design and results.

Temperature (C)	Temperature (F)	Wetting Interval (Hours)	Mixture Ratio (Gin:Dairy)	Completion (Days)	Cumulative COD (Grams)	Methane Potential (Liters)
24.7	76.4	4	2:1	27	1281	4355
25.0	77.0	4	8:1	37		
27.6	81.6	12	2:1	16	1026	3488
28.3	83.0	8	5:1	23	780	2652
29.0	84.2	12	8:1	18	964	3278
29.9	85.8	24	5:1	21	1024	3482
30.5	86.9	8	5:1	23	1182	4019
30.9	87.6	8	1:1	14		
30.9	87.7	8	10:1	29		
31.4	88.5	8	5:1	21		
31.7	89.0	8	5:1	19		
31.9	89.5	8	5:1	20	1104	3754
32.0	89.6	8	5:1	21	1154	3924
32.1	89.7	2	5:1	13	1140	3876
32.2	90.0	8	5:1	23	870	2958
36.2	97.2	4	8:1	17	931	3165
37.3	99.2	4	2:1	13	563	1914
37.1	98.8	12	2:1	19		
37.9	100.2	12	8:1	23		
43.3	110.0	8	5:1	16		

Table 2. Fecal coliform bacteria counts with and without gin trash present (Log 10 CFU/100 mL).

Time	Gin Trash & Manure		Manure Only	
(Days)	Tank 1	Tank 2	Tank 3	Tank 4
0	8.08	8.08	8.08	8.08
4	7.58	8.21	7.11	7.32
7	7.57	7.87	6.36	5.47
11	6.04	5.59	5.57	5.39
15	6.02	4.89	5.73	4.92
18	3.96	3.28	4.29	4.43
21	4.00	3.69	4.50	4.75
26	4.22	4.04	5.27	5.79

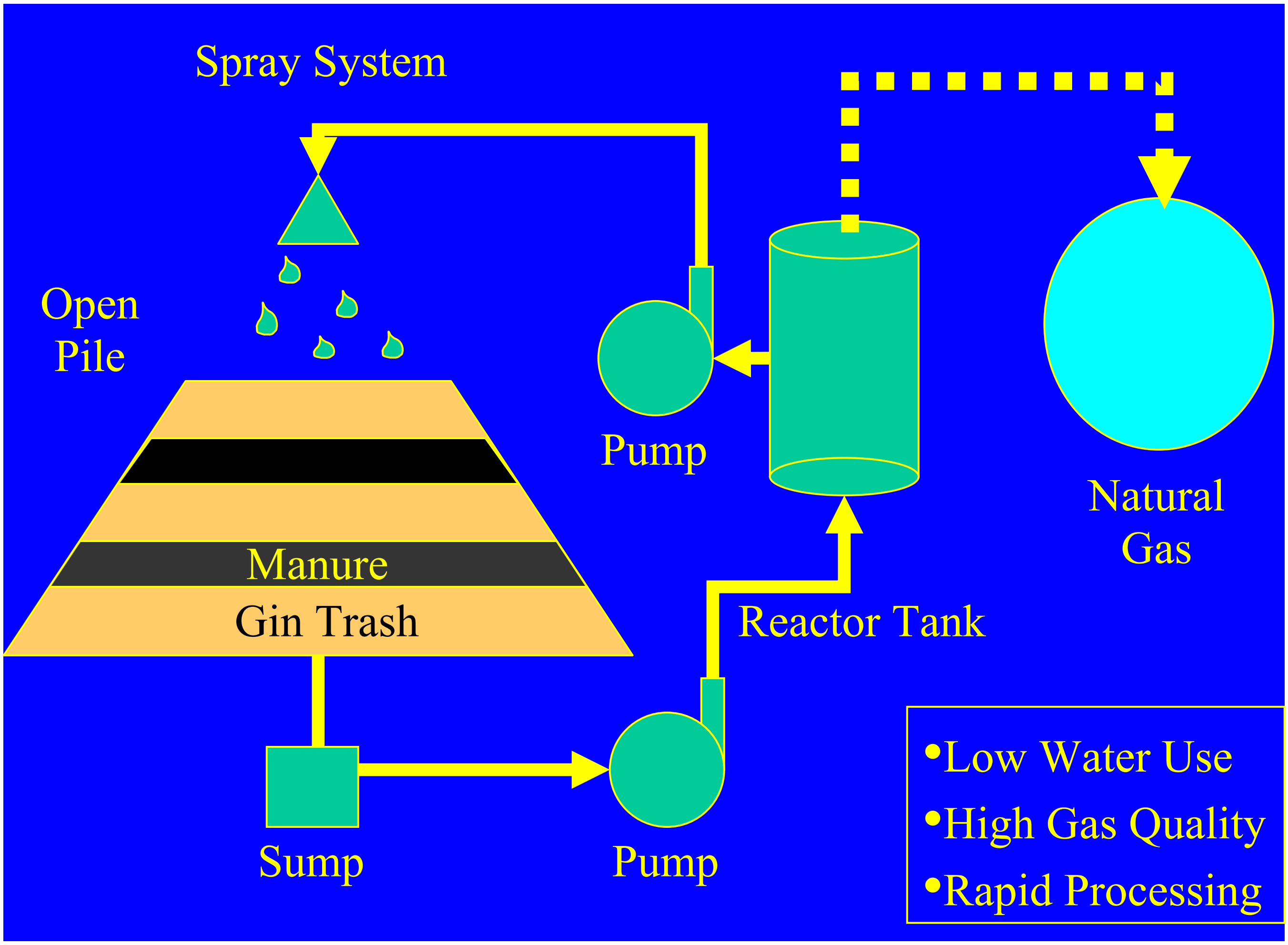

Figure 1. The two-phase biofermentation process.

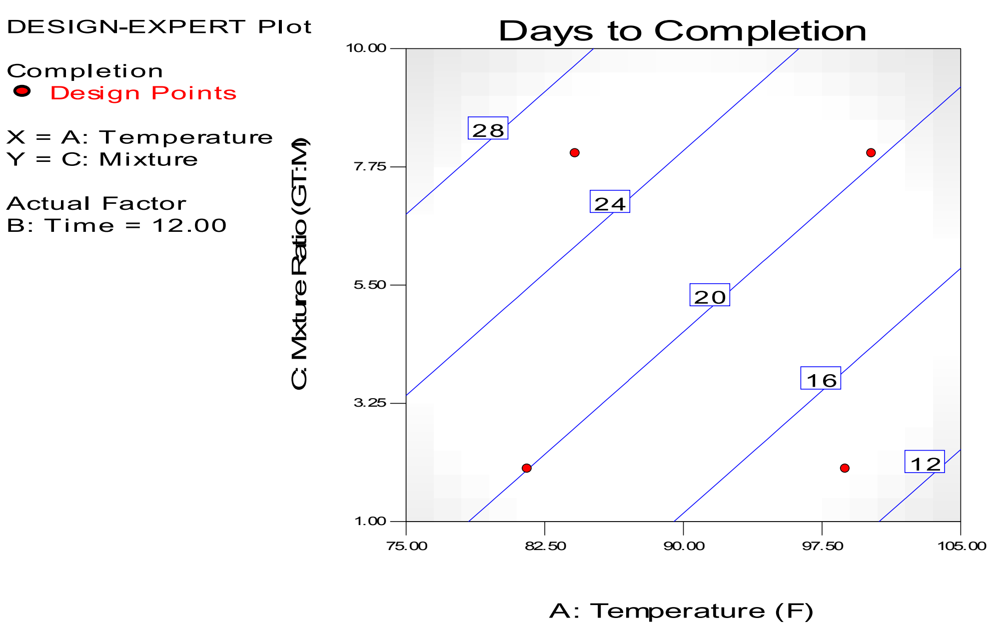

Figure 2. Days to completion (diagonal lines) as a function of solid phase temperature and mixture ratio.

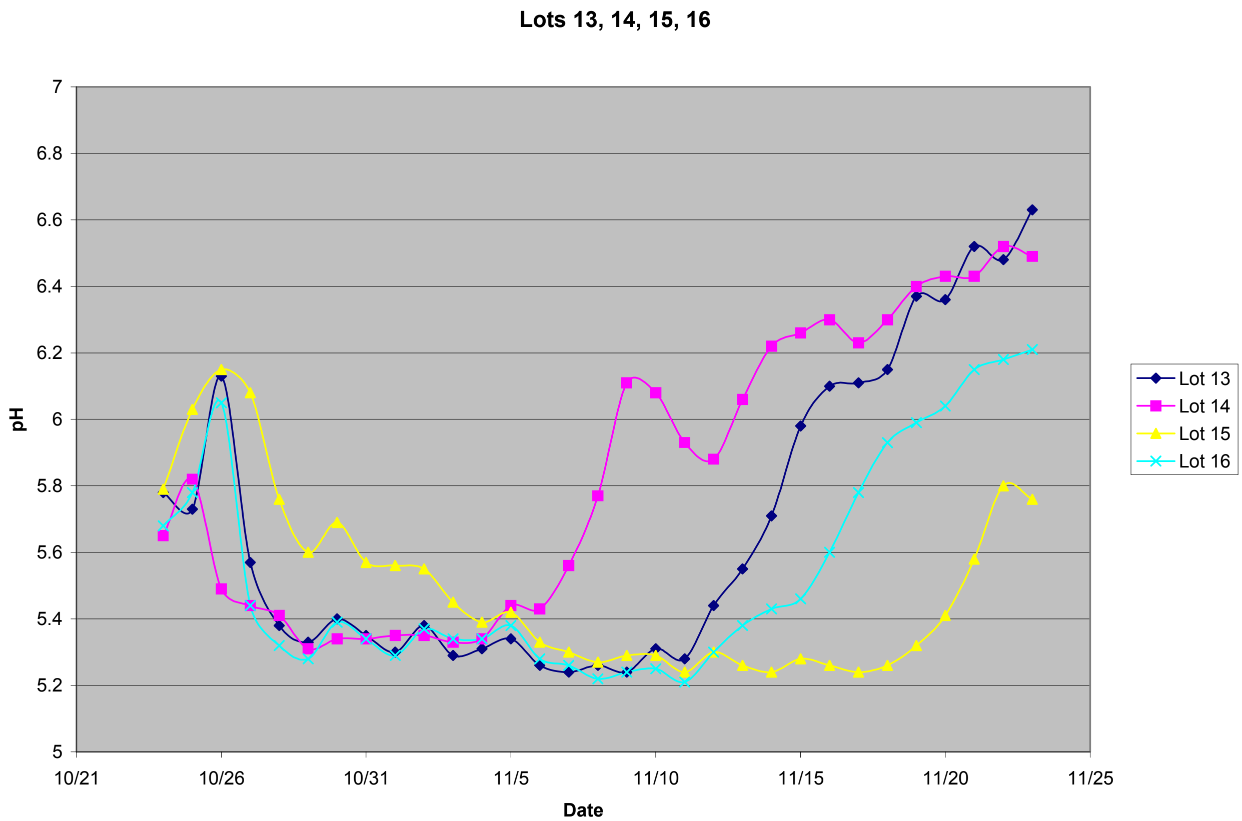

Figure 3. History of VFA production as indicated by pH level in leachate (from fourth run).

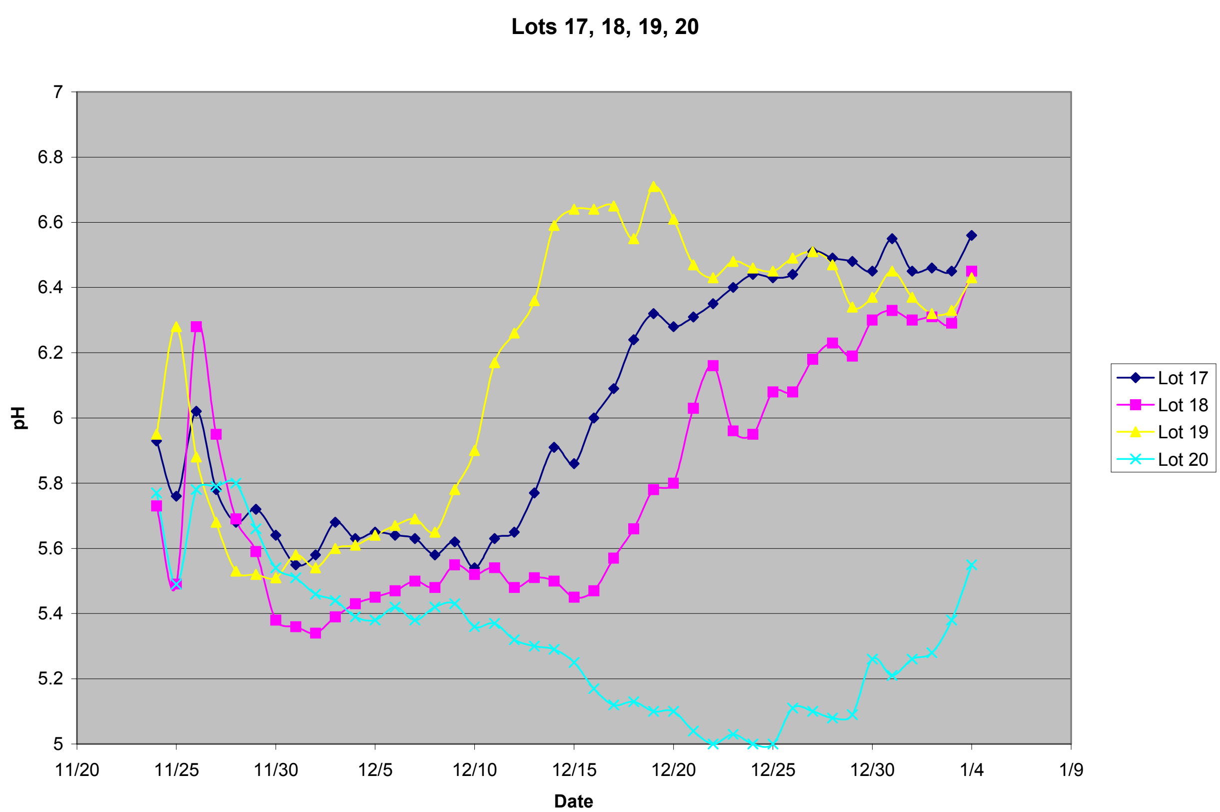

Figure 4. History of VFA production as indicated by pH level in leachate (from fifth run).